Journal of the Society of Arts.

FRIDAY, JULY 30, 1869.

Announcements by the Council.

National Elementary Training and Education.

The Council announce with regret that the review by his Royal Highness Prince Arthur, at the Crystal Palace, of the boys of the several district and other schools, in or near the metropolis, who are sytematically taught drilling as part of their education, which was to have taken place this day (Friday), is unavoidably postponed.

Proceedings of the Society.

Cantor Lectures.

ON APPLIED MECHANICS.

By John Anderson, Esq., C.E.

Lecture I. — Delivered Monday, April 12th.

Applied Mechanics in Relation to Art and Science.

The following unpretending course of lectures will have reference to a portion of the subject of Applied Mechanics, or, as it is frequently termed, Practical Mechanics.

It is needless to make any apology, at the Society of Arts, for introducing su h a subject. The important place which applied mechanics now occupies in all branches of manufacturing industry, both for peace and war, as well as in accelerating the conveyance of men and commodities, and in improving the means of communication between man and man all the world over—these combined advantages have given it such a high position in this age, that its value is self-evident and is acknowledged by all. The time has gone past when the introduction of machinery has to be defended. It is now an axiom that the man who can make two blades of grass to grow where but one grew before is a benefactor to his race; with equal truth it may be said that the man who can make two of any useful article where but one was made before is equally a benefactor. The general result of machinery is to increase the productions which supply man's necessities, and by means of which our existence is maintained. It thus provides a living for a greater number. Assuming applied mechanics to be the application of mechanical philosophy by mechanical art, or rather the subjugation of the powers and materials of nature which have been placed at man's disposal in the world, and that man being gifted with an inventive and contriving mind, he turns and applies them all, as far as his knowledge extends, to the furtherance of his own purposes, it will be convenient for the present purpose to consider applied mechanics as an art for giving to materials certain definite mathematical forms or shapes; then, the arranging of these shapes or forms under such combinations, that, on the application of any natural force, from whatever source derived, that force will produce certain and definite results by the combination. It thus embraces the subject of automatic working, and producing by the aid of machinery the various kinds of mechanism and movements which men have contrived for the application of first principles. With the aid of mathematics, it aims at the adaptation and harmonising of the best forms to be given to materials, consistent with their several chemical and physical properties and characteristics, so that they may severally afford the maximum of strength with the minimum of quantity, and at the lowest cost. From this short definition, it will be seen that applied mechanics is a large subject, which at every step is crossing the paths of chemistry, mathematics, natural philosophy, and physics. Although it is thus entwined with and depending on so many other sciences, still it has a distinguishing character of its own, and the unchanging laws which govern the material universe, and, so far as we know, the whole firmament of heaven, regulates matter it all its varied applications in the workshop; and when the practical science of the workshop or manufactory is carefully analysed, when man's mechanism and contrivances are eliminated, it is the true science of nature that remains, and which is the great leading feature, and man's province is merely to take advantage of and apply nature, and which he does *apply under* so many thousand different ways. From the circumstance that man's doings are so intimately incorporated with all workshop arrangements, our minds are naturally prone to over-estimate man's share, and to under-estimate the effect due to the simple obedience of natural laws as the grand agency for achieving such results.

The science of applied mechanics, like all true science, is founded upon a long-continued accumulation of practical facts, many, indeed the greater number, of these facts having emanated from some obscure workshop, so that their history is unrecorded; and although these facts in themselves are invaluable, and to know them simply as facts is certainly good, still it is immensely better for our young men to know the natural law which governs the facts, and upon which they are severally founded. As a general rule, the teaching of our young practical mechanics is too much confined to the facts of the workshop, and their attention is not directed sufficiently to the natural laws and fundamental principles by which they are governed, without which there can be no practical result of any kind. A knowledge of the law will explain any number of facts, and hence will facilitate the process of teaching. It was a common saying at one time, that an ounce of practice was worth a pound of theory. Without under-rating the importance of practical teaching, I have come to the conclusion that, so far as real progress is concerned, the ounce of theory thoroughly understood is worth any amount of practice without such knowledge.

It will thus be seen that applied mechanics has a two-fold character; it is a practical mechanical art, turning to account scientific natural principles. By the term art, is here meant that practical knowledge which men have acquired in regard to the working of, and the taking advantage of, the natural properties of materials, and the various contrivances for fashioning them into mathematical form, and applying them in accordance with the natural laws. By the term scientific principles, is here understood the knowledge which men, by their researches and investigations both in past ages and in modern times, have acquired in regard to mathematical principles and the general laws of nature which govern the universe.

To the superficial observer the work of the labouring artificer is generally associated with drudgery only, that any skill, or craft, or cunning which he may happen to acquire is the result of unthinking practice. While admitting that there is too much ground for such a conclusion, still it will be found, by those who take the trouble to look beneath the surface, that many of the busy workers are at the same time real philosophers, students of the laws of nature, whose thoughts and feelings have risen to a higher platform than the ephemeral trifles and delusions of the day, and it is to men of this class that our country is indebted for the large amount of mechanical progress made during the past hundred

years. From the manner in which handicraft producing operations have been regarded in the literature of the past, the world has at length almost come to believe that the science of the workshop has reached it by a deductive process from the labours of the learned and the studious. But it will be found that the opposite is more frequently the rule, and that the facts of practice discovered in the workshop have, by the inductive process of reasoning, been generalised into the natural law.

Before referring to the wonderful things that are now being done in the great working world, let us first try to realise man's early relation to the external world in which he found himself an inhabitant, and then trace the gradual connection which he would thus form with the science of applied mechanics before our day. In travelling up the stream of time to the remote period when man first began to have a glimpse of the elementary mechanical principles, history is silent. A long time probably elapsed before he discovered the general nature of the materials with which he was surrounded, and we arrive at historic times before men even knew that they were living at the bottom of an immense ocean of air many miles in depth, and that we live and move in this atmosphere just as the fishes do in the ocean of water. The first efforts would arise from the promptings of physical necessities, in the suggesting of simple expedients for obtaining food, covering for the body, and shelter from the weather; this, continued for a number of generations, would lead up to the first round of the ladder, namely, to be sensible of the value of working; then, after long-continued rude working, and by slow degrees, the mind would gradually acquire some perception of the wonderful adaptation of the human hand for work; this, in the course of time, would lead to the undertaking of mechanical pursuits of a simple nature; this, in combination with the aid of his latent inventive power, would result in the contriving of rude tools or implements to assist him in the performance of his daily occupations. By this time the knowledge of simple facts would accumulate. Without knowing anything of Newton's great law of attraction, the effect of gravity would be clearly realised, it would be perceived that any body or thing left to itself would fall to the ground; that some bodies were heavier than other bodies, bulk for bulk; that a body in motion had more force to do injury than the same body by mere pressure when in a state of rest. In this way man's knowledge would increase, and the first perception that "knowledge is power" was the dawn of civilisation. In course of time we arrive at the Tubal Cain era. We read in the Scriptures of Tubal Cain having become an artificer in brass and iron at a very ancient period—this important branch of industry, which after so many thousand years is still in a transition state, and far from perfect, and the discoveries and inventions of the past few years seem to indicate that it is only yet in its infancy. This reference to Tubal Cain gives us a point to start from; the number of facts which he necessarily knew in virtue of duties to be performed in his daily work is interesting to reckon up. He would know something of of the nature of heat, of the difference of temperature; that heat expanded his metals; that the different metals had different rates of expansion; that the solder which he employed to join his different metals required to have the same rate of expansion as the metals to be joined. He would know, as a fact, that heat travelled through metal rapidly without having the modern theory to explain it; he would also perceive that metals and other substances differed greatly in regard to the rate of conducting heat. The soldering-bolt which he employed would soon lead to the application of some slower conductor, as a handle in order to prevent it from burning his hand; at first a handful of sand, a bunch of hay, the corner of his leather apron, or at length some ingenious man would invent a wooden handle. He would soon find out that the black pan in which he cooked his dinner was a better absorber or radiator of heat than the bright and polished surface of the new pan when it left his workshop. He would know, if observing, that some substances, even if apparently indicating the same heat, really contained a great deal more than others—that when the pot of lead was emptied, the lead had less heat to give up than the pot; he would also know a little of malleability and of its opposite condition, and many other facts of a similar nature, all of which would become familiar to the first workers in metal, even if they could not generalise them into laws. Indeed, with all the advantages of modern science, we are still groping in the dark for the natural law that governs some of the established facts with which we are all familiar and daily practising. By the Tubal Cain era, man would know something of the invisible atmosphere; that it was a real substance; that when in rapid motion, as in a hurricane, it was capable of tearing up trees by the roots; that it could be employed to urge a fire; that it was the supporter of combustion. In time, he would know that it could be urged by a fan, and that such a fanner could be advantageously employed to blow the chaff from the corn on the thrashing-floor. As time went on, and men began to know that more work and of better quality could be accomplished by each confining himself to one description of duty, the system of subdividing labour may be considered as having commenced; this would be still further extended—its advantage both for head-work and hand-work would gradually become more and more apparent, until in our time it has become one of the leading features of civilisation.

It is scarcely more than a century since men discovered the advantage of manufacturing, as distinguished from the previous condition of what may be called making. During the past history of the world, the various articles required by man were made rather than manufactured, as a rule the work being performed at the houses of the workmen, the several members of the family taking their respective parts—a system which had many domestic advantages, but is associated with one great drawback, that it is not so economical as the co-operative manufacturing system. The first great experiment with the manufacturing system was made by Arkwright. He was a man possessed of great inventive talent, and a wonderful natural ability for organisation, even to the minutest details. By his genius, the principle of subdivided co-operation was developed in the cotton manufacture to its utmost limit, and which has since been extended by others into almost every branch of industry. In such establishments, by the united means of the factory system, the organisation of labour, the saving of expense for conveying the materials under operation from one stage to another, together with the efficiency of the machinery employed, the required articles are produced so abundantly and so cheaply by a given expenditure of individual labour, that the whole working-world has now begun to recognise the great advantage of the system in an economic point of view, and it is being adopted in all civilised countries.

In the early history of applied mechanics, machinery, in the modern sense, was not the prominent feature. Even up to a comparatively recent period, the inventive mind did not take hold of the grand idea of making the power of nature, by means of an inanimate machine, perform the drudgery of man's work, so leaving him to guide and direct by his intelligence. In those early days, ingenious men wasted their lives in contriving clever mouse-traps, curious clocks, and in the vain endeavour to arrive at perpetual motion, or in other similar objects which have been of no real use to mankind. Still, their labour did not go entirely unrewarded to the human race. It is to those persevering men that we are indebted for many ingenious pieces of mechanism, for a variety of mechanical motions and other contrivances, which were all ready waiting for the world to take advantage of, and to turn to better account when the time had arrived for entering upon the modern manufacturing system.

In this age it is difficult to realise the contrast between the mechanical art of past ages with that of the present day, more especially in this great manufacturing country, with our railways and steam vessels, where we are all so accustomed and familiarised with the wonderful results of applied mechanics in a general way that we have come to look upon everything as common which a former age would have looked upon as a miracle of art, that it is only by descending into details that the present position of practical art can be realised. It has been truly said that there is nothing of art existing but what was invented by somebody at some time or other; even the familiar bread-and-butter must have been arrived at by the discovery and invention of many thinking minds, in ages long gone by. It is only such a consideration as this which enables us to conceive the vast accumulation of facts of art which had to be established, one after the other, before a heap of iron ore could be worked and manipulated into any modern machine, say a steam-engine; and if such a heap of iron ore were to be piled up beside the finished engine in full operation, great as would be the contrast, it would signally fail in conveying any correct idea of the invention and discovery which it embraces, even when merely considered as a work of art, in the changing of the condition and form of the materials into the accurate mathematical piece of working mechanism. The amount of thinking and contriving which it involved is now far beyond all reckoning. Passing over the gradual discovery of the natural laws, by obedience to which the metal can be separated from the earthy matter, the discovery of the necessity and efficiency of some other earthy matter to act as a flux, and thus set the iron free; the invention of the blowing apparatus, capable of forcing such a prodigious quantity of air into the furnace, in order to obtain the requisite temperature, so as to reduce the metal to the condition of pig-iron, suitable for the founder's purposes; then comes the founding art, in which every step depends on strict obedience to certain natural laws, which had to be discovered before they could be obeyed, and before the engine cylinder could be formed into a successful casting. How numerous must have been the practical failures before the laws were reduced to a system of art that would ensure sound castings of the several parts. How many handy makeshift appliances must founders have resorted to between the time when the mould was rudely worked into the form by the hand and the period when men had learned to use a pattern, that is, to work from a copy of the required article instead of making an original of every production. What surprise must have been excited when the founder first discovered that fragile sand would bear the rush and rapid flow of the liquid metal into its most intricate recesses. Numerous were the fractured castings turned out of moulds before men understood the natural law which governs contraction in cooling, and, by dearly bought experience thus learned to obey. Then comes the accumulated facts of generations, now generalised into a law, by means of which a casting may have any degree of hardness or softness, or one part hard and another part soft, or both combined, with the property of strength and toughness.

It is the same with the smithing branch. Smithing is an older art than founding. In the olden time the smith was a great man in every large establishment, and many of the facts learned in those days have been handed down to us. But modern smithing differs greatly in most of its features from that of the past; it has become manufacturing rather than making, and involves an immense number of inventions and appliances. The smith deals with iron in the condition termed "wrought;" in this state the greater portion of the carbon which it contains in the cast-iron state has been eliminated or burned out, and by a process of working, either by hammering or rolling, it acquires the fibrous character, with fully three times the strength of the former. Between the two conditions there is a wide gulf of apparatus to be surmounted—the devising and inventing of the various furnaces for refining, puddling, and welding, the invention of rolling mills, cutting-machines, and steam-hammers—before a modern bar of good wrought iron can be produced. When we look into a large smithy, and see the multitude of labour-saving articles, each of which had been invented by some one between the time when the smith worked with the hammer and hand entirely, and the present day, when the various articles are produced by the numerous modifications of the principle of copying. In some the viscous mass of red-hot iron is placed within an iron mould, and by the blow of a steam-hammer the malleable material is made to flow into the required form, for this material, although the most valuable, is at the same time one of the most difficult to fashion into shape, in consequence of its unyielding toughness; hence it is that the steam-hammer stands out as the great smithy improvement of modern times.

In the modern steam-engine, the piston and other important parts are made of cast or Bessemer steel. Here another field of invention opens up. Think of Huntsman's struggles in the early days of cast-steel—the difficulty with his crucibles, and the heart-sickening failures which he had to encounter and successfully grapple with, before we arrived at the quality of modern cast-steel. Then comes the secret wonders of the hardening and tempering process, which has come down from a remote period, by means of which we can obtain any degree of hardness, or temper, or toughness, to suit the innumerable purposes of art. Still, we are a long way from the steam-engine. It is now interesting to read of the struggle with almost insuperable difficulties that had to be encountered at the Soho Works of Boulton and Watt, before men knew how a cast-iron steam-engine cylinder could be bored out correctly—the many makeshifts that had to be resorted to before the law became known that, with the cutter moving at about 16 feet per minute, it could be successfully accomplished. Then came the invention of the boring-bar, and all the other appliances which seemed to flow spontaneously from the fertile minds of Wilkinson and Murdoch, and by means of which Watt's great invention was brought to a successful issue. Still more important are those marvels of mathematical refinement, the modern copying tools of an engineer's workshop. The invention and introduction of the block machinery by Bentham and Brunel was the first effort on a grand scale to apply the principle of copying by transfer instead of the form being arrived at by the hand and skill of the workman. The sliding rest or tool-holder principle, as an amateur instrument, had been in partial use for a number of years upon the Continent, but Henry Maudslay was the first to render it a practical reality. Then Mr. Whitworth and others arose to give the system that crowning precision which we daily see, in which the principle of taking the mathematical lines from a copy by transfer, combined with being self-acting, is the great feature.

In this hurried sketch of practical mechanical art, frequent reference has been made to the principle of production by copying. Enough, however, has not been said to show the position which that principle occupies in all art-arrangements within the scope of applied mechanics in modern times. To produce the mathematical figure from some variously-contrived modification of a geometric copy is the aim of almost all invention in connection with production, as distinguished from obtaining definite form by the hand-skill of former times. It will be found, on going over any modern factory, that every thing which is done well, and at the same time done cheaply, is accomplished by means of this copying principle. A clear understanding of this as a principle will go far towards simplifying and explaining the greater number of modern shaping and other machines, by whatever nomenclature they are known. First, there is the subject to be accomplished; second, the mathematical principle or natural law to be

employed; and, third, the mechanical contrivances that are introduced by man to carry the principle into effect. Copying has thus become so interwoven with everything that we daily see that its employment goes unnoticed, and hence the vast advantage that the modern world derives from it, in almost every branch of art, goes unappreciated. We read of only one artist who at any time, and with a sweep of his hand, could draw a perfect circle, yet by copying with a pair of compasses, a true circle is produced by anyone, without any trouble. How few can draw a straight line with a pen; hence we have recourse to a straight-edge or ruler, as a standard from which we draw any number of straight lines by copying. We write our letters by hand, but quickly take a copy by transfer. The editor writes his leading article slowly, and probably very badly, so far as the penmanship is concerned, but see it in the morning impression of the *Times* newspaper, produced at the rate of 10,000 copies per hour by this principle. Or, to take another direction, to the class of things we see in our houses. The bricks, even when made by hand, are made in a mould as a copy, and the principle is still further developed in the brick-making machines, which are constructed on many different arrangements, but all form the brick by transfer. It is the same in plastering the walls. In former times the plaster was laid on in the beaver fashion, but now two straight-edges are established, and a third straight-edge is transversely employed to transfer this combination of straight lines, on the same principle as the planing-machine by the engineer, but in both it is merely copying. In forming the cornice, a profile template is made of the proper section, and is drawn along upon a straight-edge, and between the two the cornice is developed. When the plasterer resorts to flowers or other ornaments, he does not make them, he employs a mould to copy from. The copy was made carefully, by an artist probably, hence it was expensive, but by copying the produce may be equally good, and at a price within the reach of everybody. Passing to the working of wood, the baulks of timber as they are imported into England are rough and uneven, because they are squared up by hand with an adze, not by copying. When it passes to the saw-pit, the sawyer chalks a cord, stretches a straight line upon one side of the baulk, and giving the string a jerk he copies straight lines, to which he guides the saw in its gradual progress. In the sawing machine we have all the art of the plasterer's straight-edges, or the engineer's planing-machine; the baulk moves in a straight line, the saws move in straight lines at right angles, and thus produce parallel boards. In wood-planing it is the same; the hand plane-iron of the carpenter is a mere chisel when not fixed in the block of wood, but the lower side of the block being a flat surface, the chisel is approximately guided by the wood so as to transfer its flat surface to the board by copying. In wood-planing machines, the copy principle is a still greater development; the straight lines are given to the parts of the machine, some one way, in some by another arrangement, but all agreeing in this principle, that the conditions of surface or form are first given to the machine, and then these conditions are given again and again to the wood submitted to its operation, quickly, perfectly, and cheaply. Similar remarks apply to the carpenters' tools for mouldings, and beads; like the plasterer, in forming the cornice, the carpenter has a steel copy of the required moulding made for him by a tool maker; this is inserted in a corresponding block of wood, and it becomes the moulding plane. In the moulding machine, the said plane iron, so cut to pattern, revolves on an axis, the spindle is held at right angles, and the wood is passed along in a straight line. All these conditions are transferred to the wood by copying. Passing to metal, we find everywhere the same tendency. As a rule, all the iron and brass articles in our houses are made from a copy, the gas and water pipes by a die, the fire grate and all its belongings are transferred from a pattern, the ornamental parts of our chandeliers are derived from dies; so that throughout the whole range of art whatever in our houses is beautiful and good, and yet within the reach of moderate means, is produced by transfer from a copy instead of by making. This question of price is not a small matter, as those of limited wealth, equally with the more affluent, have pleasure from being surrounded with the comforts and elegancies of civilised life; and the introduction of such ornaments into working men's houses tends to refine the character, increase the self-respect, and to raise them in the scale of being; but it is entirely due to the copying principle by means of which it can be accomplished. Whichever branch of modern practical art we choose to select for illustration, or in whichever direction we wander, it is all copying by some means or other. Take bank notes; they are printed from a plate that was transferred from an original plate, which was made at great expense. The coin of the realm is struck in dies, these dies being the offspring of other dies, which originally had been made by hand. Bullets are made in dies or cast in moulds; bayonets are drawn out in oscillating or revolving dies; the tapering gun-barrel has its precise form in the rolls; wire of any section is drawn through a die; ornamental tubes as well as plain are copied from the apparatus; and in all these various productions the copy is the important point, the mechanical apparatus is merely an agency which may be varied at the constructor's pleasure.

Rising to the more important manufacturing operations, it is still the same story, that the great prominent feature of modern mechanical art is production from copy by transfer, instead of by hand as in the olden time. The most superficial can see that the rough mass of iron, in being passed through the rolls, is made to undergo two changes—the shape of the groove in the rolls gives form, and the pressure of the rolls, considered as endless or revolving dies, gives a flowing elongation. In the case of rolling plate or sheet it is the same, the distance between the rolls is the thickness, the smoothness of the rolls determines the smoothness of the plates. Power is employed to turn the rolls round, the friction draws the iron inwards, and all combined, this invention of Cort is one of the grandest examples of copying of modern times.

Let us turn to the slide-rest principle again, and examine it a little more closely as a copying agency, and likewise in regard to the immense variety of application of the principle to the most dissimilar machines, such as a lathe or a planing machine, a machine for slotting, or a machine for turning screws, or cutting the teeth of wheels, besides numerous other machines of different names that are employed in other branches of manufacture, such as those for small-arms and other war stores. A close inspection will reduce the dissimilarity very considerably, down to a very few modifications of slide-rest copying, combined with some mechanical expedients which are the alphabetical letters of applied mechanics, and may be set up into any number of arrangements, like letters into all the words in the dictionary. And what is still more important, these producing copying machines are the offspring of other machines of the same kind, and will, or may in their turn, produce all other kinds of machines of the same family likeness, *ad infinitum*.

In looking back to the early days of the old turning-lathe, before the introduction of the transfer principle of the sliding rest, it is interesting to observe that even then the lathe was a perfect instrument in so far as it was a copying machine. Those early lathes that were made with a perfectly round neck to the spindle, if any such existed, would yield a round figure in the article under operation, providing that the cutting-instrument was held steadily, and even a still higher degree of truth or roundness was obtained by the now old-fashioned dead-centre lathes, in which the article turned upon its own centres, the surface, developed by holding the cutting-instrument steadily would be as round as the circle described with a pair of compasses. With all such

apparatus, however, the chances of error were numerous. The spindles were not round, and it was next to impossible for the best workman to guide the instrument either in a straight line or any other definite figure. In all modern machine-tools the correct mathematical figure is given to the apparatus, either as a perfect circle in the lathe-spindle, or as straight lines in the lathe-bed, saddle, or slide-rest, planing, slotting, shaping machines, or otherwise. In the case of a lathe, whether arranged horizontally or vertically by various adjustments, any figure is transferred, true circles, true cylinders, flat surfaces or even straight lines, straight lines approaching to a point, thus forming cones. The leading screw can be made to transfer itself or its own opposite, right-hand or left hand; or by driving it faster or slower it will transfer screws of any other pitch, coarser or finer, to the right or to the left, and all this is accomplished without the assistance of the attendant workman beyond the first adjustment, the cutting tool being held in an iron hand, which can only move in the line or lines intended, the quality of the work depending entirely on the correctness of the machine, whether for good or bad. In all the other machines it is the same principle differently arranged. In some the article to be operated upon is made to move in a straight line, or to revolve upon a true surface, and the instrument is held over or at the sides. In others, it is found more convenient to hold the article instead of the instrument, and the instrument is moved in straight lines or circles, or otherwise. In others the instrument is held by an iron arm and moved horizontally or vertically, or in any or every direction. In some the cutting instrument revolves, and is moved over the article, or the article is moved under the revolving instrument; or to select an exceptional machine, that for cutting the teeth of wheels, here we have a circular cutter the form of the space between the teeth, this is held in what may be termed a sliding rest, and thus a copy of both combined is imparted to the wheel, and even in regard to the division of the pitch of the teeth, it is exactly the same principle, the division is contained in the machine as a copy, and may be altered at pleasure by the use of toothed wheels serving as multipliers or dividers, or otherwise. Or if we look at the numerous ways of forming screws, as in bolts and nuts, and such like, it is all done by transfer from what are called taps or dies variously arranged, but in all the apparatus is the copy of what is required, just as much as it is in the machine for turning lasts for shoemakers, or gun-stocks for the War Department, although not perhaps quite so apparent. In the gun-stock making machine an exact copy of the form is the prominent feature—a tracer transfers this figure to the instrument that cuts the rough stock into shape. In the case of any description of rifling machine for cutting the spiral groove within a gun, in order to form what is called a rifle, a bar containing the cutting-instrument is introduced into the bore of the gun, and the gun becomes the sliding-rest, the spiral movement is given to the bar, which may be derived from a spiral on the bar itself, or from a straight line set at an angle, or by other means, but in all the lines are taken from copy by transfer.

It would only become tedious to go on enumerating examples; enough has been said to show the importance of the copying or transferring principle in modern mechanical art, still it is too frequently lost sight of in the literature and teaching even of the present time; and although this general principle of working from a copy, instead of fashioning by hand-skill, may seem familiar to us, and may appear as the natural course to pursue, still that condition of mind only goes to show the great advance which the world has made in applied mechanics during the past 100 years, and although we may almost wonder that the world was so long in seeing its advantages, yet so it is with everything. Man is slow in realising the value of a great principle, and its progress is gradual, and no doubt there are many things lying hid from us now, covered over with a thin veil, which will be equally clear to the greater art-knowledge of a future generation.

Applied mechanics has so far been considered as an art, because it appears to be the natural order; first, the simple facts of practice, then these facts carefully compared with each other, and their points of agreement rapidly scrutinised, until at length the philosopher is able, by the inductive process, to generalise the facts into the general law that governs them. At the same time, it is not always so; many of its grandest achievements were deductive. Take Watt and the steam-engine. Black's speculations on the theory of latent heat prepared Watt's mind for the separate condenser; this heat could not be traced as a fact; it was absorbed and apparently lost, but by a process of reasoning downwards it ultimately led to one of the grandest facts in practical science. Another example is the case of the learned Pascal, in regard to the laws which govern fluids. It was by a deductive process from certain discoveries of Torricelli in regard to the atmosphere, that Pascal discovered that the pressure of fluids is equal in every direction, and so thoroughly did he investigate this subject that little has been left for his successors to improve upon. It was more than 100 years before this knowledge was reduced to practical account, first by Bramah in the well-known hydrostatic press, and which has been so ably followed up by Roger, by Sir William Armstrong, and others. But it will be found that in all modern water-pressure machinery of any description, and however variously constructed, that Pascal's grand law is the leading feature, and by understanding which, all the facts founded upon it are explained. It will thus be seen that all have their work to do, and if the division of labour is a sound principle in the workshop, so it is also in the study and the laboratory. We require those with the time and the talent, as well as the learning, to dive deep into the hidden recesses of nature which are yet unexplored, and whose province it is to place in a simple form the knowledge of natural laws thus acquired within the reach of those whose duty it is to carry it into practice.

After referring so much to man's doings in connection with mechanical art, it seems almost presumptuous to pass so abruptly to the laws of nature, which act over the immensity of space, as compared with these, the greatest work of man is insignificant. Still, by his ingenuity, he takes advantage of the power and laws of nature in thousands of different ways, and by his skill organises their application into all branches of mechanical art and manufacture. My object in the present lecture is not so much to explain the laws or principles in themselves, but rather to draw attention to some of the more familiar laws, for the purpose of referring to their application, and likewise to some of the various contrivances by means of which man turns them to account. By way of pre-eminence, I select, first, the grandest scientific discovery ever made by man, namely, the universal law of attraction, which was revealed to the world by our own immortal Newton, and, strange although it may appear, it will be found that this great law, under its conventional names of gravitation, cohesion, or capillary attraction is constantly in operation in all our busy workshops. With the law of gravitation we are all familiar, in its formation of a dew-drop, or a tear, or that two globules of quicksilver, placed side by side, run together and form one globule. An interesting illustration of the action of this law, upon a small scale, is seen in the manufacture of leaden shot, in which the same law that formed planets into spheres is to be seen in daily operation. The lead is melted at the top of a tower some 200 feet from the ground; the metal is poured into a kind of sieve or cullender, and passes through the holes by gravity; as in the case of rain, so here the metal separates into drops; by falling through the air, these drops lose sufficient heat to render them solid before reaching a cistern of water at the bottom. When lead is employed by itself, for want of fluidity, many of

the balls are imperfectly formed, and hence. a small portion of arsenic is mixed with it in order to obtain greater fluidity, thus giving the law time to act; for when the lead sets too quickly the perfect sphere is not accomplished—it is more of a pear-shape, but with a certain liquidity each atom is drawn to a common centre into a perfect sphere. Still more instructive is the phenomenon when the metal is too liquid from an overdose of arsenic, for then, by remaining too long in the liquid state, the little ball acquires a whirling motion before it is a solid, and, like our little world, the centrifugal force acquired from its whirling motion throws it beyond the sphere into the form of an oblate spheroid.

So far, we have two illustrations of the law—first, in forming the drop into a sphere; and next, in drawing the drops of lead down to earth; but gravity has yet another office to perform, in separating the good from the bad, and in the assorting of them into their respective sizes. When the spheres are afterwards collected, many of them are found imperfect, besides being of different dimensions. A very simple but ingenious application of the law is employed to separate the good from the bad. They are all run down an inclined plane; those that are pear-shaped run off at the sides; those that are perfectly round acquire such velocity from gravitation sufficient to carry them over certain pitfalls in the way, and so they reach the bottom in safety; but the remainder, that are not so round, do not acquire a velocity sufficient to carry them over the pitfalls, and so they drop through, and along with the other imperfect ones are gathered up to be re-melted. The whole of the good spheres, of all sizes, are then collected and poured into the upper end of an inclined revolving cylinder, having a succession of holes of different sizes upon its outer surface. As this cylinder is continually turning round, gravitation is lying in wait, and the small shot are drawn through the small holes, and fall into a box on purpose underneath; then the next size fall through other holes into another box, and so on until all are disposed of.

The kind of attraction commonly called cohesion is another modification of the same great law. In its usual acceptation it refers to the force by which the molecules and atoms of the same body are held together; but when we bear in mind that the force of gravitation is inversely as the square of the distance of the centres apart, when the particles of the same body are in contact, they may be many thousand times nearer to each other than when only separated by the ten thousandth part of an inch. As a rule, in the practice of applied mechanics, the engineer is most frequently called upon to prevent the rupture of cohesion, from the effect of some extraneous force superior to the inherent attraction of its own particles. Still there are many exceptions, and most engineers are familiar with instances of separate substances becoming united from their having been permitted to approach too closely to each other, thus allowing the natural law to assert its superiority, and which it will invariably do whenever it has the opportunity.

It is a fact, well known to those who are engaged with the softer metals, that if two pieces of lead have their pure metallic surfaces laid bare, and then put together with pressure and a twist, they will unite and become as one piece. It is not so generally known that two dissimilar metals will unite in the same manner, say steel, or iron, or brass, with lead. In the manufacture of leaden bullets by compression, where the dies have to plunge into the solid lead, it is found that, after a short time, the steel will unite with the lead, and become one conglomerate mass, hence it is necessary in all such processes to introduce some unctuous matter to prevent contact, and so hinder the law from acting. This cohesion does not take place because the metal lead is soft; it certainly requires less pressure on account of the softness, but it arises from the two metals coming together with pure metallic surfaces while under pressure. The same result may happen with hard surfaces if they are perfectly clean; even two pieces of glass that are made truly flat and clean on their surfaces will join together in the same way. A case occurred with two pieces of hard steel, six inches in diameter. Previous to the introduction of the present methods of taking the thrust of the shaft of a screw propellor in steam vessels, the thrust was received by a fixed piece of steel, a corresponding piece of hard steel forming the end of the shaft; the two came into actual contact, from the absence of oil, water, or other medium, and so became united, the shaft breaking elsewhere. Surfaces so flat, so purely metallic, and with so much pressure, are fortunately rare, but we frequently meet with an approximation to the conditions, and which, for convenience, is usually termed adhesion. Adhesion is usually considered as the union of dissimilar substances, but is this strictly correct? Is not the union between the steel die and the lead just as much the attraction of cohesion as that of the two pieces of lead or steel? The difference of term has probably arisen from the circumstance that when two dissimilar masses are thus united, they in course of time drop asunder; this dropping asunder, however, proceeds from another law of nature, a much more inexorable law than that of attraction, a law which man frequently tries to disobey, but the penalty is invariably inflicted. It is the law of expansion by heat and contraction by cold, and the variable rates of expansion and contraction of the different substances in nature that separates them. When a piece of iron is soldered or riveted to a piece of brass at some definite temperature, all is well, but when the heat is increased, the brass expands more than the iron—then commences the struggle for liberty of action; the elasticity of the materials comes into exercise as a peacemaker, but the natural law will act, by bending the structure, that is to say, the longer piece of brass will form the outside of the curve; then, as winter comes round, the contrary effect is produced, and the brass is the inner ring of the circle; so, when lead is thus united to steel, the greater expansibility of the lead causes it to strive for liberty by a wriggling process, carried on probably for years, until at length the law of attraction is defeated.

There is yet another modification of the great law, which, for convenience, is called capillary attraction. It is that property of liquids whereby they rise in tubes or other porous substances of any kind, even in a bunch of glass threads, of iron wire, ropes, or woods, or even between plates that are near to each other. Now, in this simple process, there are three forces at work, all in obedience to the great law; first, gravitation pulling the fluid downwards; secondly, the attraction that draws the atoms of the fluid to each other; and, thirdly, the attraction of the bundle of fibres, or the sides of a tube that draws the fluid upwards. From this it follows that the smaller the tube, or the closer the bundle of fibres, so the higher will it rise in proportion. All are familiar with this law in ordinary life. The corner of the towel in a basin of water empties the basin; the oil rises in the wick of the lamp; the engineer employs it to oil his machinery by a cotton wick introduced into lubricators; but in applied mechanics it has many varied duties to perform, and its irresistible effect has frequently to be guarded against as well as taken advantage of. When a rope or a piece of wood is subjected to its influence, the bulk of the mass is increased; and in the case of a twisted rope, the fibres are drawn in by the enlargement, and thus the rope is shortened. When a dry wooden wedge is driven into the crevice of a rock the wedge swells and splits the mass. Until a few years ago, all grinding-stones were fixed upon their axles by means of dry wooden wedges, driven into the space between the axle and the stone. After a time the wedges became wetted and swollen, for a while the strength of the stone resisted their efforts, until it became reduced in diameter by wear. Then the natural law, with the aid of centrifugal force from the velocity of the stone came into play and scattered the mass into fragments, at the cost of

many a poor grinder's life. In modern arrangements man has become more obedient—he now grips the stone sideways between two discs of iron, thus removing the splitting action of the wedges, and at the same time anticipating and providing for the effect of centrifugal force.

Those who have lived in tents well know the effect of rain in shortening the ropes, and thereby pulling out the pegs by which stability on the ground is maintained; but, it is not so generally known that a very heavy mass, such as the anvil of a steam-hammer, may be raised a short distance without the usual tackle, by simply tightening a bundle of dry ropes over it by means of a long pole, then wetting the ropes, when they necessarily become larger in diameter, and at the same time shorter; by this means any mass that the ropes are capable of sustaining will, in obedience to the law, be made to swing. It is said that when the statue of a celebrated hero was in the act of being raised to its present elevated site, the rope slings had so stretched by the great weight, that the blocks became foul of each other when the statue wanted but a very small distance of being at the required height, so that it might swing over upon the top of the column. The engineers who were engaged in raising it, after exhausting their skill in useless efforts, were about to lower it to the ground as a lost attempt, when an old sailor in the surrounding crowd, who saw their difficulty, and who knew the natural law, called out, "Wet the ropes;" the hint was taken, and produced the desired effect. Knowledge is always power.

The law that governs the pendulum is another kind of example of extensive application in practical mechanics, although even the pendulum law is dependent upon Newton's great law of attraction. The discovery of the pendulum law was made by Galileo, who, next to Newton, was perhaps one of the greatest philosophers who ever lived. We are all familiar with the story, that, while still a young man, he was sitting one day in the metropolitan church at Pisa, through some cause, one of the lamps suspended from the ceiling was set in motion, and, from its great length, continued to swing backwards and forwards for a long time afterwards. He was struck with the circumstance that it took the same time to make the long swing at the commencement when first disturbed, which it did to make the shorter swing just before coming to the state of rest. There were no clocks nor watches in those days, but by means of his pulse he managed to verify the fact, and with further experiments after he went home, fully confirmed and revealed the law of the synchronism of the pendulum. When of equal length, at least within certain limits, that, when the pendulum is raised at one side by the hand in opposition to gravity, the same amount of work is necessarily bestowed upon it by gravity during its descent which is sufficient to carry it to the same height at the other side, and but for the resistance of the atmosphere, and the friction of the rod, would go on continuously. This discovery may not have seemed of much value at the time, but it has turned out to be of the greatest importance to the world. It is the best measurer of time which man has yet found out. Before many years had passed, it was turned to practical account by Huygens as a clock regulator, a clock being simply a piece of mechanism to count and show the beats of the pendulum in a given time, with a weight to counteract the resistance of the air and friction. This, in time, led to the application of the balance-wheel for watches; for man, one getting hold of a clue, did not rest until he found out that a small spring could take the place of gravitation; for what gravity is to the pendulum, the little spring is to the balance-wheel; both pull to a centre of rest, but the work or force then stored up carries it as far the other way; and as a substitute for the weight of the clock, the main-spring is introduced into the watch, so as to overcome its little friction and other sources of retardation. The world had gone on many thousands of years using the plummet, before Galileo's time, but no one had previously observed that it contained the pendulum law, and but for the circumstance that the knowledge fell into the hands of that great man, it is quite possible that no other man might even yet have ascertained it. The steam-engine and water-wheel regulating governors, with which we are all more or less familiar, are but modifications of the pendulum principle combined with other forces, and, to a certain extent, are governed by its laws; and the probability is very great that, but for the knowledge of Galileo's pendulum, James Watt, even with all his unrivalled powers of invention, would have gone off in some other direction, in seeking for a principle on which to construct a governor for his engine. Thus it is that real science is ever making way. A true position once taken is never given up; errors are gradually discovered, and eliminated, and forgotten, but the laws of nature will hold their own to the end of time. During the past 100 years machinery-governors have been constructed on many different arrangements, the greater number of them are on the pedulum principle, but in none of them have we reached the extreme simplicity of the old pendulum. As a rule, man's first efforts in every kind of machinery construction is complex, but, as time advances, the thinking tear and wear of different minds, gradually render it more and more like to the simplicity of nature.

Before leaving the pendulum law, let me refer to another kindred law, that of inertia, which is that property of matter whereby it will continue in its present condition, whether at rest or in motion, unless it is interfered with from without. As this is a subject on which some practical men have unsound views, mostly traceable to the old notion of *vis inertia*, a term still to be found in some books on natural philosophy, artillery, and mechanics. There is no such principle in matter as that word implies, the only property is that of passiveness, inactivity, or inertia. Matter is as willing to be in motion as at rest, and as willing to rest as to be in motion; the same power that is required to set it in motion is required to stop it again. This error has affected arrangements in all past times, and it is only of late years that the minds of engineers have begun to shake off the thraldom. The whole principle may be explained by the pendulum. A portion of strength equal to gravitation is expended in raising it; when the ball is set at liberty, gravitation again performs the same work during its descent; if stopped when at the bottom, the same work that was performed by the right hand has to be expended upon the left hand; if the pendulum is not stopped, then the force stored up in it will carry it up until the gravitation resistance balances the previous force of acceleration from gravitation, but the ball itself is perfectly passive, and is without any living principle to influence it one way or the other. It would be interesting to trace the mental working of those engineers who are gradually breaking through the practice that was founded upon a misconception of the natural law. Familiarity with the reversing of railway and marine engines has shown it to be inertia merely that has to be overcome either in setting in motion, in stopping, or reversing, and this accounts for the rapid introduction of coupled reversing engines of light construction and without fly-wheels during the past five years, and nowhere more perfectly than at Crewe, by Mr. Ramsbottom.

Passing to another of the natural laws in connection with the atmosphere which plays a most important part in applied mechanics, we have there a striking example of the intimate relation that exists between science and art. Although this law is apparently inconsistent with gravitation, in that lighter fluids ascend through heavier, as in the ascent of balloons, or the draught in chimneys, yet this law, like that of the pendulum law, is equally dependent on the law of gravitation. It is merely in obedience to that great law that the heavier air of the atmosphere descends, and the specifically lighter air in the chimney or the balloon is floated upwards. The ship floats on the water because, bulk for bulk, the ship

is lighter than the water; so the balloon, bulk for bulk, is lighter than the air, hence it rises in the great ocean of the atmosphere.

In ancient times men were fully acquainted with the raising of fluids, such as water, and of the existence of the air. They even made machines, such as pumps, to take advantage of the air-pressure, yet they had no idea of the laws by which it was regulated; hence it was a blind groping in the dark until the law was understood. It was as well known to the world two thousand years ago as it is to us that water would rise in the pipe of a pump to about 30 feet, but, not knowing the true cause, they invented an explanation, as men do now when they are groping in the dark, and as we constantly are in regard to many things. The explanation was that the water rose in the pipe because " nature abhorred a vacuum." It was in the middle of the 17th century that Torricelli discovered the law, and then all mystery was removed, and we now know why nature abhors a vacuum, or why the water rises in the pump. The story of Torricelli's discovery has been often told and is well known to all, yet is always interesting to the young mechanic. A pump was being erected in Florence; it was deeper than ordinary, and commanded some little attention at the time. During their leisure hours, we can picture the intelligent young lads of that Italian city gathering around the new pump. When it came to be tried, for some reason the water would not come up. We may imagine all sorts of coaxing being resorted to, water poured in at the top to induce other water to follow, but to no purpose, and they were obliged at last to abandon it as a lost attempt. The great Galileo was consulted. He was now a man of mature age, and was considered the greatest man of his time. It is said that after consideration he gave it as his opinion that nature abhorred a vacuum up to a certain height only; but this, I consider, to be a very doubtful statement. The youth Torricelli, who was a favourite pupil of Galileo, did not feel satisfied. He possessed a clear intellect, and in farther reflecting over the matter, it occurred to him that the atmosphere might have something to do with it; that possibly when the pump was worked the air might thereby be exhausted, and that the surrounding atmosphere resting on the surface of the water in the well would thereby push up the water into the empty space in the pump. Still he had only a glimmering idea, when a most happy thought suggested itself. He said, "If the atmosphere has something to do with it, then mercury, which is 13½ times heavier than water, would not rise above 28 inches; if I fill a tube with mercury, having one end closed and the other open, then by immersing the open end in a cup containing that liquid, the mercury will not run out, but remain at a height in proportion to the weight of the atmosphere." The experiment was made, the mercury stood at nearly 29 inches; according to the laws which govern liquids it ought to run down. There must exist an enormous pressure equal to some 34 feet of water column, but by some agency was prevented from running down. What can prevent it from heaving up the liquid mercury in the cup? It must be the equally weighty atmosphere resting on the surface. It was afterwards ascertained that the atmosphere rests on the earth's surface with a pressure equal to 14·7 lbs. on every square inch. No sooner was the law of the atmospheric pressure discovered than it began to yield fruits. Up to this time there was no barometer, nor did Torricelli yet know that he had actually invented one. Before many months the rumour of the new theory reached France. It was the celebrated Pascal who, on hearing of the discovery and the inference deduced from it, made the remark that it might be put beyond all doubt by making the experiment beside a mountain, and, by proceeding up or down, the mercury would rise or fall as the column of air was decreased or diminished. The experiment was accordingly performed beside a mountain, and the result was exactly as had been anticipated. The world had now obtained its valuable instrument the barometer, and this again soon led to other results, and eventually to the invention of the steam engine, which, as originally constructed, was entirely dependant on the pressure of the atmosphere for its efficiency. Before two years the knowledge of the discovery had reached England. Among the first to hear of it was a noble youth, the Honourable Robert Boyle, who longed to make the acquaintance of Torricelli. He went to Italy, and was in time to see the last days of the great Galileo, who died in 1643. But the news of the discovery had spread into Germany. Otto de Querricke, the Consul of Magdeburg, is busy trying experiments with the well-known hemispheres, and is struggling with the invention of an air-pump for the purpose of exhausting them. These hemispheres, in their day, were a great invention, and rendered all the more interesting from the circumstance that it was by means of them that the attention of mankind was first drawn to some of the properties of air. The inventor, Otto de Querricke, had two hemispheres made, about a foot in diameter; he had no air-pump, but by some means managed to get out the air by first filling them with water, and then pumping it out, at the same time taking care to prevent air from getting in. It took the world by surprise. We read that the hemispheres were pressed together so powerfully that six of the emperor's horses were unable to separate them. By the experiments with the air-pump, Otto de Querricke discovered the elasticity of air, and added greatly to the world's store of knowledge regarding the whole subject. During these experiments, he was visited by Robert Boyle, who, by his ingenuity and perseverance, gave to the air-pump, that well-known form in which it has been handed down to us, with the exception of a few recent improvements.

Before twenty years these discoveries began to bear fruit in other directions, for, in a small town in Holland, in the year 1663, we find this knowledge of the pressure and elasticity of air being turned to practical account. At that time the Dutch were the great engineers of Europe, and occupied that place in engineering that we now hold. John Vander Heydon was a great engineer, with considerable practice in the erection of pumps, but, to his frequent disappointment, he found that when he had to give an intermittent motion to water there was constant danger of either breaking the pump or of bursting the pipes, arising from the non-elasticity of the water. Happening to hear of the Torricellian experiment, and also of the doings of Otto de Querricke, it now occurred to him that he could introduce an elastic cushion of air into the pipes, so that the immediate effect of the piston would be to compress the air, when the air by its elasticity would produce a constant stream of water outwards; this he carried out into practice, and it answered most admirably. Before he was aware, Vander Heydon had really invented the fire-extinguishing engine, and by the end of that year the first fire-engine was constructed, in which the discharge from the pumps went to compress the air in a central air-vessel, the elasticity of the air being the agent to send the continuous squirt of water outwards. Since that time the air-vessel has been applied to every extensive ramification of water-pipes, but the world should not forget that the first idea in modern times belongs to Vander Heydon. I have said modern times, because that great man Hero, of Alexandria, 120 years B.C., had a fountain in his courtyard, constructed on a similar principle.

In this hurried and most inadequate sketch, a feeble attempt has been made to show the relation that subsists between art and science in a small branch of applied mechanics, my chief object being to forward the teaching of the simple principles and laws of nature in every school, and to all the youths who are to become our future workmen, to let them know that there cannot be a practical result of any kind without a fundamental principle, and that before entering the workshop their

minds should be well grounded in the unalterable laws on which their work is founded. Such knowledge encourages the mind for practical duties, and prepares it for grappling with the multifarious questions that are continually arising, and will prevent them from falling into practical error.

The simple principles of the mechanical powers, which were so well known by Archimedes, have, by the perseverance of man, during many ages and in many countries, become the refined mechanism of our factories and workshops; yet, with all the profound sagacity of his mind, he did not perceive that such simple elements could admit of so many combinations and arrangements. Therefore, in our pursuit after the economic application of natural law, we must not overlook these other natural laws that may not seem now to bear so directly on our industrial operations. Time and study will adapt them all to some useful purpose, by the well-directed thought of a future Watt, or a Stephenson, or a Whitworth.

Proceedings of Institutions.

EXAMINATION PAPERS, 1869.

(Continued from page 705.)

The following are the Examination Papers set in the various subjects at the Final Examination held in April last:—

ALGEBRA.

THREE HOURS ALLOWED.

1. Multiply $a^3 - 7a^2 + 5a + 1$ by $2a^2 - 4a + 1$, and show that $a.\dfrac{x + a + \sqrt{x^2 - a^2}}{x + a - \sqrt{x^2 - a^2}} = x + \sqrt{x^2 - a^2}$.

2. Investigate a rule for finding the highest common divisor of two algebraical expressions.

Simplify the fraction

$$\frac{x^7 - 3x^6 + x^5 - 4x^2 + 12x - 4}{2x^4 - 6x^3 + 3x^2 - 3x + 1}$$

3. Show that, in the ordinary scale of notation, a number is divisible by 9 if the sum of its digits is divisible by 9.

4. Determine in what cases $x^n \pm y^n$ is divisible by $x \pm y$.

Find a factor which will rationalize $\sqrt[3]{2} + \sqrt{3}$

5. Solve the equations,

$$\frac{x + 7}{2} - \frac{x + 2}{3} - \frac{3x + 7}{12} = \tfrac{1}{4}$$

$$\left.\begin{aligned} x^2y + xy^2 &= 180 \\ x^3 + y^3 &= 189 \end{aligned}\right\}$$

6. If h be a root of the equation $ax^2 + bx + c = 0$, show that $ax^2 + bx + c$ is divisible exactly by $x - h$.

7. If $\dfrac{a}{b} = \dfrac{c}{d}$, and $\dfrac{m}{n} = \dfrac{p}{q}$, prove that $\dfrac{ma + nb}{ma - nb} = \dfrac{pc + qd}{pc - qd}$ Show that, if any number of fractions be equal, each is equal the nth root of the fraction of which the numerator is the sum of any multiples of the nth powers of the numerators, and the denominator the sum of the same multiples of the nth powers of the denominators.

8. Show how to insert n harmonic means between a and b.

9. Prove that the number of combinations of n things taken r together is the same as the number taken $n - r$ together.

10. Write down the rth term of $(a - x)^n$

What term of $(1 + x)^{-\frac{1}{2}}$ is equal to thirteen times the same term of $(1 - x)^{\frac{1}{2}}$?

11. A man has a capital of £A, which he invests at r per cent., and every year he spends £a. What will be his capital at the end of n years, supposing him to invest any overplus he may have at the end of each year at the same rate per cent?

12. Determine the series of which the sum of n terms is n^2.

Find also the sum of the squares of n terms of the preceding series.

13. Given p the probability of an event happening in one trial, find the probability of its happening r times exactly in n trials.

GEOMETRY.

THREE HOURS ALLOWED.

To obtain a first-class certificate at least six problems and four propositions must be correctly done; and to obtain a second-class, four problems and six propositions.

1. Define *right angle, circle, square, parallel lines.* What is an axiom? a *Postulate?* Write down Euclid's XIIth Axiom. Why is it wanted?

2. If two triangles have two sides of the one equal to two sides of the other, each to each, and have likewise their bases equal; the angle which is contained by the two sides of the one shall be equal to the angle contained by the two sides equal to them, of the other.

3. If one side of a triangle be produced, the exterior angle is greater than either of the interior opposite angles.

Draw the figure for both cases.

4. If two triangles have two sides of the one equal to two sides of the other, each to each, but the angle contained by the two sides of one of them greater than the angle contained by the two sides equal to them, of the other; the base of that which has the greater angle, shall be greater than the base of the other.

5. If the square described upon one of the sides of a triangle, be equal to the squares described upon the other two sides of it; the angle contained by these two sides is a right angle.

6. Divide a given straight line into two parts, so that the rectangle contained by the whole and one of the parts, shall be equal to the square of the other part.

7. The diameter is the greatest straight line in a circle; and, of all others, that which is nearer to the centre is always greater than one more remote: and the greater is nearer to the centre than the less.

8. From a given circle cut off a segment, which shall contain an angle equal to a given rectilineal angle.

9. Describe a circle about a given triangle.

10. If the outward angle of a triangle made by producing one of its sides, be divided into two equal angles, by a straight line, which also cuts the base produced; the segments between the dividing line and the extremities of the base, have the same ratio which the other sides of the triangle have to one another: and conversely, if the segments of the base produced have the same ratio which the other sides of the triangle have; the straight line drawn from the vertex to the point of section divides the outward angle of the triangle into two equal angles.

11. In right-angled triangles, the rectilineal figure described upon the side opposite to the right angle, is equal to the similar and similarly described figures upon the sides containing the right angle.

12. Planes to which the same straight line is perpendicular, are parallel to one another.

13. If a solid angle be contained by three plane angles, any two of them are greater than the third.

PROBLEMS.

1. If the middle points of the sides of a triangle be joined, the triangle so formed is one-fourth of the original triangle.

2. If two sides of a triangle be given, the triangle will be greatest when they contain a right angle.

3. Divide an equilateral triangle into nine equal parts.

4. In any triangle the squares of the two sides are together double of the two squares of half the base, and

of the straight line joining its bisection with the opposite angle.

5. Three points being in the same plane, find a fourth point where lines drawn from the first three shall make given angles with one another.

6. Given a regular polygon, find another which shall have the same perimeter, but double the number of sides.

7. Show how to divide a given line in harmonical proportion.

8. The diagonals of a trapezium two of whose sides are parallel, cut one another in the same ratio.

9. Given the lengths of the three straight lines drawn from the angles of a triangle to the points of bisection of the opposite sides; construct the triangle.

10. If a circle be described about a triangle, and perpendiculars be drawn upon the sides from any point in the circumference; the three points of intersection are in the same straight line.

(*To be continued.*)

SANITARY PRINCIPLES OF COTTAGE IMPROVEMENT.

On Saturday, the 17th instant, Mr. Edwin Chadwick gave a "garden tea party" to the committee of the Ladies' Sanitary Association, to the Council of the Society of Arts, and to others interested in the sanitary improvement of dwellings, at his house at East Sheen, for the purpose of showing some new forms of construction, and especially for displaying a new mode of ventilating with air—both warm and fresh—invented by Capt. D. Galton, R.E., in a new model cottage, occupied as a gardener's lodge, attached to his house, on principles which were explained in an address. Amongst those present were the Earl of Shaftesbury, Sir P. Burrell, the Right Hon. W. Cowper, Henry Cole, Esq., C.B., Arthur Russell, Esq., M.P., George Melly, Esq., M.P., Frank McClean, Esq., C.E., Colonel Murray, R.E., George Godwin, Esq., F.R.S., Professor Owen, Dr. Farr, Dr. Sutherland, Dr. Aldis, Dr. Garth Wilkinson, J. Rendle, Esq., Hyde Clarke, Esq., J. Bell, Esq., the Secretary, and the Assistant Secretary of the Society of Arts; the Hon. Mrs. Cowper, Madame Bunsen, Miss Geraldine Jewsbury, Miss Mary Macaulay, and Miss Griffiths, the Secretary of the Ladies' Sanitary Association. The Dukes of Buccleuch and Devonshire, and Lords Fortescue, Stanley, Cawdor, Northbrook, and Ebury sent letters expressive of regret that previous engagements prevented their being present on the occasion.

Mr. Chadwick addressed the company, as they were seated in the garden, as follows:—My Lord, Ladies, and Gentlemen,—I shall have difficulty in conveying, within any compass, for this occasion, my sense of the great importance of the rising movement which may be aided by the principles of the construction of the very humble-looking little cottage to which I have besought the honour of your visit. The sanitary object attainable by the improvement of the dwellings of the wage-classes is no less than a reduction of nearly half the prevalent premature disability from sickness, and half their mortality, which is proved to be due to the conditions in and about their dwellings, including over-crowding. The Society of Arts has promoted new arts, such, recently, as pisciculture and oyster-culture, which are being earnestly pursued, with a special solicitude as to the habitats of the creatures as the chief means; and it may really befittingly promote, as a new or as a neglected art, on which the progress of other arts must depend, puericulture, for which earnest solicitude as to the habitat is also needed, and for the result of which there is great promise; for we have had of late, from medical officers and heads of establishments, evidence that is consolatory for past efforts of sanitary improvement, displayed in district orphan asylums of the metropolis—most striking to those who have visited them, as I have done, after lapses of time; that as the common lodging-houses have been regulated under Lord Shaftesbury's Act, and the low courts and dwellings—former fever-nests—from which these orphan and destitute children chiefly come, have been improved by rudimentary measures of a sanitary police, the type of children has been improved; they become less ugly, and ferocious, and repulsive in their aspect, and the school teachers attest that they are less difficult to teach and to train industrially. In this view of the mental and moral, as well as the physical improvement of the population, I may, I hope, suggest to the noble ladies of the Sanitary Association that the principles in question have, moreover, claims upon them in respect to the extension of an improved order of marriages, and the reduction of a demoralising celibacy amongst the wage-classes; for, of the million and a-quarter of men of the marriageable ages who remain single, has it been seriously considered how many are withheld from marriage by the want of befitting homes;—how many are deterred by having only places presented to them which are dark and filthy, deprived of due light and air (yet dear) to which they could take a wife;—how many are deterred by the aspect of squalid misery they witness on the part of the married, of whom, in Manchester, Liverpool, and Glasgow, even in times of prosperity, large proportions are born only to die, and of all born one-half, as Dr. Farr's dire records show, are in their graves before their fifth year? Of a sound, well-trained, industrial, self-supporting, and productive population, I assert as an economist, that notwithstanding the present depression of the labour market, our country needs more population, especially to supply the increasing claim by emigration, which is commonly of our best population, leaving behind larger proportions of the dependent, the pauperised, and the worst. But practical sanitary science affords brighter prospects. Large aggregations of orphan and destitute children in the institutions, such as those to which I have referred, were formerly, notwithstanding high dietaries, the seats of devastating epidemics; but now, with clean air, clean persons, and clean constructions—with yet much to do—these same institutions have become sanitary standards, with death-rates less than one-fifth of those prevalent amongst children of the same ages of the general population. My confident belief is that, by the rudimentary sanitary principles and practical sanitary art, to which I would now solicit your attention, as applied in the model cottage you will see, the death-rate amongst children and the common insurable disability to work on the part of adults may be reduced to one-third of what it now is. In various model dwellings the death-rates have been reduced by about one-third, but, unhappily, with economical results which do not encourage, and, indeed, rather discourage, imitation. By the application of the principles of construction you will see displayed, I have a confident expectation that the greatest reduction may be effected, with a better promise of a "commercial return." The great sanitary evil to be contended against in the cottage and house site and the habitat for puericulture is damp, which lowers temperature and lowers strength; generates painful diseases—rheumatism—and, lowering strength, predisposes to all other passing causes of disease, and especially to consumption. The first article to be insisted upon in a sanitary specification is, that by drainage of the site if it be necessary, "the water-table shall be lowered not less than three feet below the surface." Throughout the country it has been of late observed that a diminution of consumption has followed good subsoil drainage works. In this particular instance, the site being a deep gravel, in which the water-table is several feet below that minimum, there was no necessity for this precaution. My first condition of a sanitary preparation, as respects the construction of the house itself, is "that the flooring shall be impervious to rising wet, the walls to driving wet, and the roofing to falling wet or to snow, and that they shall be absolutely damp-proof." As illustrative of the conditions of the common constructions, I may here

mention that the common bricks of which cottages are made, absorb as much as a pint or a pound of water. Supposing the external walls of an ordinary cottage to be one brick thick, and to consist of 12,000 bricks, they will be capable of holding 1,500 gallons or 6½ tons of water, when saturated fully, which they sometimes are. To evaporate that quantity of water would require nearly a ton of coal well applied. These bricks give off their moisture slowly. It is unsafe to inhabit, in less than nine months or a year, the houses constructed of the common materials; and almost a double death-rate has attended recently the occupation of a brick-built model dwelling. When I examined, as a reporter, the model dwellings built at Paris by the Emperor, I found the appearances of damp on some of them that had been built two years. The *concierge* who showed one block had her head bound up, and was suffering from an attack of rheumatism, connected with the dampness of the houses. The Empress has since paid attention to the subject, as I am informed and I hope, with better effect. But it is proper to mention, as showing how little is to be expected, not merely from architectural science as it is, but from curative science when uncombined with preventive or sanitary science in construction, and also as showing that the poor are not the only persons who suffer, that the medical officers at the recently-constructed hospital at Netley have been afflicted with rheumatic fever, arising from the excessive dampness of the brick construction of their quarters. Some military officers' quarters, constructed chiefly, I believe, of stone not long ago at Dover by an eminent civil architect—which is often as bad as brick—were, I am assured, so damp, that it was found to be impossible to occupy them, though they had cost one thousand pounds each. A gallant friend, who the other day examined the cottage I shall show to you, exclaimed, "What superior officers' quarters such cottages would make," though they would cost one-tenth the sum expended on the damp construction at Dover. I think it right to mention these things in illustration of the common state of information on the question. The opportunity of my constructing a model cottage, as I may call it, arose from the need of erecting a new lodge for my gardener and his mother, in lieu of one enlarged from a two-room to a three-room cottage, built by my predecessor as tenant to this house—my learned friend, the Hon. Adolphus Liddell. He is a man, as everyone who knows him is aware, of solid virtues, who would be the last to do harm to any living creature. If he happily had had a ray of sanitary science, he would have been aware that in keeping the poor woman in that cottage he was victimising her, as happened, with rheumatism, from the damp brick floor and the damp walls and ceiling. His regret at what he unwittingly did to this poor old woman by the common error will be sharpened when he learns that it was at double the expense of the construction by which I trust she will now be relieved. Parliament has—in what shall I say—conferred great sanitary powers, not upon a Minister of Health, but of all men upon the Secretary of State for the Home Department, from whose visible occupation with other subjects you may see what is his power of attention to that subject. Now, it may be mentioned, as a point of observation for the Sanitary Commission now sitting, that his only adviser within the office, so far as I am aware, for the selection of sanitary officers and the exercise of very large sanitary powers must be, on very important questions for the health of populations, the permanent Under-Secretary of State, my predecessor here, the Hon. Adolphus Liddell, who, I should be glad to hope would find, amidst the multiplicity of his other duties, some small scrap of time to amend his deficiency of sanitary knowledge, of which his old lodge, which you may see here, may be presented as a monument. H.R.H. the late lamented Prince Consort, with whom I had correspondence on this question, accepted completely the principle of the dry, damp-proof construction, and endeavoured to apply it by hard-burned hollow bricks, glazed for interior wall facings. I *undoubtedly* consider that a construction of vitreous tiles or bricks the best possible, but for trade reasons, stated in my report on the exhibition of model dwellings at Paris, they are unattainable at present. The late Captain Fowke first directed my attention to concrete, as the most advantageous and the cheapest material available for cottage construction, and gave some specimens at the South Kensington Museum. Portland cement is a stronger material than Roman cement, and, as was shown at the International Exhibition, its use is extending throughout Europe. Those who wish to be informed particularly in relation to it will find all about it in the report of the Children's Employment Commissioners—that it originally imbibes less water than the common brick material, parts with it more rapidly, hardens and becomes utterly impermeable to water. My specification, "that the walls and ceilings shall be impermeable to water or damp," is complied with in this instance by the contractor, Mr. Nicoll, by the use of a new material for wall and roof construction, of which Portland cement concrete forms a part. You may imagine, as adopted for houses, the Crystal Palace principle of construction, with iron framing and bearers, but, instead of glass, opaque slabs, made of a web of straw compressed to about one-fourth the space of loose straw into a mat, which is spread over a framework of iron wire. Upon this compact web of straw, layers of hard bitumen are put on both sides. Over the bitumen is placed a layer of concrete. If the bitumen be of sufficient thickness and hardness, and properly spread, it appears impossible that wet can penetrate that walling; and although the outer layers of concrete might, if not well made, for a time, imbibe some portion of moisture, it could not pass through the bitumen. The straw, kept dry—and it should be kept completely dry,—by the bitumen—is, as we know, a non-conductor of heat, and the bitumen should be preserved in hot weather by the non-conducting power of the outer layer of concrete, which is also an entire non-conductor of damp. *Mistakes* have been made with the first attempts, in carrying the economy of the iron framing too far, and occasioning cracks in the roofs; but two years and a-half experience of a lodge on this principle of construction at South Kensington is very satisfactory. The next articles of a sanitary specification applicable to cottage construction are, "that the walling shall be washable," "that it shall be such as not to harbour vermin," and "that it shall be of a light, agreeable colour." It is a sanitary rule, as applicable to closely occupied dwellings, that the walls shall be cleansed at least once a-year, and some authorities have required that it shall be done at least four times a-year. To provide for lime washing it has been provided that the brick walls of the Peabody and other model dwellings shall be kept bare. At the Board of Health, at epidemic periods, when houses were struck with fever, we ordered the inmates to leave, and the houses to be cleansed. In some instances the orders were disobeyed, and fresh population came into the uncleansed houses, and they were attacked with fever, proving the deleterious quality of the deposit on the walls. The cost of lime-washing, as often as it is required to be repeated, is a serious tax. In hospital-construction the cost of the washable wall facings is often as much as ten shillings a superficial yard. You will see the sort of wall facings that have been given by Mr. Nicholl in the several rooms or the cottage at from one-tenth to one-twentieth of the hospital prices. The way in which the sanitary specification that the flooring shall be of a good non-conducting material, and be water-tight and damp proof, you will see is attained by squares of the cheaper wood laid upon a layer of bitumen. The occupant attests that this flooring, which you will see, is a great immediate improvement in comfort. So far as the shell of the cottage is concerned, it is submitted that it is an

improvement on the principle and the quality of construction upon the common dwellings. If the workmanship be good—and the contractor ought to be held to make good for a period of time all defaults from the sanitary specification—I do not see that the dilapidations will be greater, and I do believe they will be less, than in the common constructions. The contest is for reduction of price as well as for improvement in quality, and the economy may be achieved at the expense of stability, unless the point be guarded against, but, at the worst, I do not believe that the new construction can be so bad as the more common old one. Constructions in most forms of entire concrete walling appear to be better in quality, and may be lower in price, than brick, where good sand, or gravel, or other wall material is close at hand. But if the three-inch walls of this cottage construction have sufficiently good non-conducting power, or as good non-conducting power as the common nine-inch walls at the same price, they give an important gain in space. The cottage you will see has a gain of 564 cubic feet of interior space from three-inch instead of nine-inch walls; and, by having the entire space up to the roof, there is a gain of 720 cubic feet, or in all 1,284 feet more; that is to say, space such as in some constructions would be considered to suffice for two more persons. This is an undoubted gain for the next great point of a sanitary specification:—"That the ventilation shall be (that is to say in cold weather) with air that is warm as well as fresh." All common modes of cottage ventilation ventilate by cold air, and are almost invariably contended against by the inmates. The new method of ventilation, invented by Capt. Douglas Galton, R.E., by a fresh-air flue, in which the air is warmed, has been experimented upon in this country, and tried in a number of barracks. It has been tested by Dr. Park, of Netley, as to the hygrometrical condition of the warmed air, which he pronounces to be satisfactory, and he tells me that he intends to apply the principle to his own dwelling. It has also been carefully tested in many experiments in Paris, by General Morin, of the Institut, and, undoubtly, it is in principle a decided success. The soldiers in the barracks warmed by it declare that they are no longer, as heretofore, roasted in front whilst they are frozen behind. By this method the air may be changed three times an hour, or oftener; and nearly fifty per cent. of the chimney heat, now wasted, brought back into the room. Though the ventilation is, of course, the most active when the fire is alight, it was found, upon experiment, that from the continued warmth of the flues and the mass surrounding the flues, the change of air effected was considerable, even as late as six o'clock in the morning. The concrete is peculiarly adapted for the construction of tubular smoke and air flues at a cheap rate. This, as far as I am aware, is the first instance in which the important principle has been applied to a cottage, and until we have a winter experience, it cannot be pretended that the best adjustment of the fresh-air flue, and the means of warming it by the chimney flue, have been attained. According to General Morin, the ventilating chimney is a means of saving fifty per cent. of the coal consumed in domestic fires; and the estimated consumption of coals in our domestic fire-places is forty millions of coals annually. I commend to your notice a newer arrangement, by Mr. Nicoll, by which the same fire-place that gives radiant heat, and warming, and ventilation to the front room, keeps a boiler and an oven at work in the next. This is already reported, on trial by the housewife, to be a success. In conclusion, I may state for consideration another article of a sanitary specification, which will be realised here:—"That the complete construction of the house shall be such that if it be left clean, unoccupied, and closed for any time, it shall remain dry, free from any close, musty, or foul smell, and shall be immediately habitable, without the need of fires or of any special preparations for safe occupancy in winter or in summer." This cottage is detached, and unconnected with any system of sewers; and the plan in use here is a moveable pail under a seat, into which pail is to be put all the soap-suds, house-slops, &c., which serve to dilute excreta, the whole being removed daily, or before decomposition can commence, and deposited in a trench, or applied, at the discretion of the gardener, as liquified manure, the principle of the plan being to take the manure to the prepared soil, instead of bringing prepared soil to only a part of the house manure, as is the principle of the earth-closet system. Where the house is connected with a public system of sewerage, which, it is to be hoped, would be a self-cleansing system of sewers instead of sewers of deposit, which are only extended cesspools, the fundamental item of a sanitary specification, I take occasion to state, would be in the following terms:—"The house shall be provided with a water-closet on the syphon principle, so shaped, and so provided with water as to be effectually self-cleansing throughout, and to remove at once from beneath the premises all fæcal matter or waste water, and to be so trapped as to prevent the ingress of vitiated air from the sewer in the event of accidental stoppages, and to be at all times free from foul smells." Now, as to the cost of this cottage construction. My conclusion is that an improved cottage construction, on whatever principle, will be only obtainable when cottages become a manufacture (which is not yet), with the advantage of much machinery for the repetition of numbers. I think acknowledgments are due to Mr. Sharp, the architect, and to Mr. Nicoll, the contractor, for their steady efforts to reduce and to keep down prices. I am assured by them that detached cottages, such as the present specimen, with 4,800 cubic feet of internal capacity, may be repeated, in half a dozen at a time, for about one hundred pounds each; or, if a dozen cottages in a row (where it must be so, for I do not like cottages in rows) be taken of the same qualities, guaranteed damp-proof, but without decorations, at about eighty-five pounds each. These (apart from the present main question of quality and economy in use) are, as far as I know, important reductions in prices. To the members of the Ladies Sanitary Association, who do so much with little money, who have circulated such admirable tracts on the sanitary treatment of children and on domestic management, I respectfully commend the promulgation of sanitary principles for the improved construction of the people's homes. The first of these principles is the requirement, by specification, of dry foundations, of dry and warm floors, of perfectly damp-proof walls and ceilings, walls washable and fair to see, and means of ventilation with air that is warm as well as fresh, saving half the common consumption of fuel, and giving really comfortable homes. To my colleagues of the Council and to the members of the Society of Arts, I venture to commend the consideration of the perfectionment of the arts and appliances by which these several ends may be best attained for the poorest of the population.

After the delivery of this explanatory address, the party went to visit and examine the cottage. Time did not admit of any technical or professional discussion, and the company separated with general expressions of gratification to the host and hostess with the afternoon's proceedings.

We are requested by Mr. Chadwick to state that he will gladly allow the cottage to be shown to any member of the Society of Arts who has a special interest in the subject, and that he will be thankful for any suggestion of further improvements.

PATENTS AND PATENT LAWS.

By W. Bridges Adams.

The word "monopoly" is one of exceeding ill-odour with the great mass of the community, and to affix such

a name to patents is considered a very clever move on the part of their opponents. It catches the public ear, and the public is very apt to take things for granted that appear to conform to its interests. What is a monopoly? A privilege conferred upon special individuals, for their own advantage, to the disadvantage of the community. At first sight numerous private rights appear to be monopolies—land, mines, forests, rivers, the raw material of the world, which are the property of the whole human race, as tenants in common; and for individuals to possess and own them as private property is simply a concession granted, because they will produce a generally greater fruit by the process of individual enclosure than by a general scramble. The conversion of the raw material into useful forms, by the operation of the human brain and human hands, creates another kind of property, giving the raw material far greater value by mental and physical labour, labour which would not be given unless the owners could reap some of the fruits of it by an enclosure of the results of their own brains or hands as their own property. Origination of new and useful ideas and forms, producing something better and more useful than has been produced before, is the most valuable kind of labour, and therefore the world, in proportion as it becomes civilised, gives exclusive property, for a longer or shorter time, to the producers of the ideas, and goes still further in giving hereditary rights to long-continued industry.

Language is common property; but the author of a book, putting language into new forms in combination with ideas, is endowed with what is called "copyright" for a term of years, a monopoly, in short, for the reason that, without that monopoly, the books would not be produced, or only a very few books would be produced by a few wealthy and powerful persons; and the very title of the book is also a monopoly. Another person produces a picture which has a high value, and the right to reproduce that picture by engravings, or photographs, or other means, is reserved to him. Another produces new combinations of musical sound, and the multiplication of copies of this music is as much his own property as the original. Another produces a piece of sculpture, with the same results. Another produces a new design for furniture, or patterns for dress, or other manufacture, and that is as much his own, with the exclusive right to sell it entire or in copies, as though it were the corn and cattle of the farmer, or the fruit of the orchard owner, or the vegetables of the market-gardener.

This monopoly goes still further. The style and title of a firm is private property; and, as if to guard against the contingency of the same Christian and surname in combination being used for competition by a namesake, trade-marks were invented to ensure the monopoly, and every possible means are resorted to, to prevent a trader's individuality from being trenched on by his neighbours. Yet more, a proprietor of a newspaper, with no individuality, and who purchases all his wares ready made from other persons, has the exclusive right to a particular word or combination of words out of a dictionary, which, if he be the first to assume, no one can appropriate till he chooses to abandon his right.

Throughout all these things it is the right of property which the law jealously guards, mental or other. But for this law, a large mass of mankind would disguise themselves in their neighbours' likeness, to reap the profits accruing from their neighbours' reputation.

What are called patents are mental originations, multiplied in matter, and the law professes to confer on the originator the sole right to use and sell them to the public for the course of fourteen years. Some of these originations are very popular, and an enormous trade grows up, from which large profits accrue, and it is very commonly an article not of real importance to the welfare of the community that makes the largest profits; but whatever it may be, trade rivalry is excited, and any means are resorted to for evading the patent without payment to the inventor. Everything previously known in the trade is at the disposal of the rivals, but the Naboth's vineyard they covet is the new thing which the public prefer, either for its superiority or its cheapness, and which has been the production of the inventor's brain. So they set to work to defame him, to deny his originality, to call him a monopolist, to decry his invention, to try to evade it by inferior methods, and, finally, to take advantage of inefficient laws to plunge him into costly trials that may ruin him and put the invention out of use, if they cannot appropriate it to themselves without paying anything for the cost of its production.

A few years back, an attempt was made to decry and abolish patents at the meeting of the British Association, and now once more an attempt is making to obtain a huge monopoly, under pretext of abolishing another—not a monopoly as of old in the case of the corn-laws, for the benefit of landlords or landowners, but for the supposed benefit of trade-lords and capitalists generally. Large manufacturers, material converters, and similar people, desire to get the use of brains without paying for them, or to keep things as they are. It is not a case of patentees against the community, as their opponents endeavour to make out, but a case for the community itself, as interested in progress, against wealthy traders who would keep down all progress, if by so doing they could keep up their own profits. It is the case of the community, in behalf of the active brains that work for them with mental capital, and without material capital, against the dull and inert brains with material capital in masses, which at present, stimulated into competition by the restless brains around them, lead an uneasy life, and would fain become the slaveholders of the active brains, and prescribe limits to their labours under their own control, and for their own imaginary benefit. It is an attempt to create an hereditary trade aristocracy by taking away the fulcrum through which clear brains rise into the possession of material capital, and their owners elbow the inert rich from their seats. And, not uncommonly, it is those who have grown rich upon patents who are the most strenuous opponents of other men's patents.

The common ground of opposition is that patents impede progress. If they did, that would be sufficient reason for their abolition. But assertion is not demonstration. It is asserted that the patent is a monopoly which no one but the owner can use. Quite true; but so is land a monopoly which no one but the owner can use, the difference being that the patent is a monopoly for fourteen years, and the land for ever. The patent is a fourteen years' monopoly of individual brainwork, the land monopoly is that of the material works of the Creator. If the land were the property of the State, the rentals would belong to the general community as a tax-fund, and the community gives it to individuals on the supposition that they will manage it better for the general benefit of the community than the State could, the rental being the payment for their trouble. The patent is a limited property, the land is an unlimited property, both conferred by the community, and capable of resumption if demonstrated to be mischievous to the community.

The brain-worker can only, in the case of patents, operate by the agency of matter, the property of the landlord, who exacts a large share of the brain-work in return for the use of the matter. But the brain-working patentee has no monopoly. He is exposed to the competition of all others using the landlord's matter, or the materials of the Creator, save in the patentee's particular mode. And no sooner has he achieved a success, than other inventors are immediately at work to eclipse him, to the benefit and advantage of the public; and it is notorious that, even in the case of a successful invention not superseded by another improvement, commonly half the fourteen years' term expires before an invention is brought even into limited use.

The large manufacturer has his choice of patents by competition amongst brains, saying nothing of the stored-

up records of lapsed patents at the Patent-office, which he rarely has recourse to, save to compete with, and defeat, something new, which a rival manufacturer has produced under a patent, and turned to profit. It is well known that few manufacturers will embark in new things without the protection of a patent, for the reason that money must be expended experimentally, and that rivals lie in ambush to reap the profits in competition, without outlay, and consequently can undersell the originator, and for this reason the records of lapsed patents in the Patent-office are not resorted to, but remain dead letters.

It has been sought to make a distinction between copyright and patent-right. There is none; they are alike, in their integrity, original emanations of the human mind, and we may be quite sure that the abolition of patents would soon be followed by the abolition of copyright in books or works of art. Copyright in designs is copyright in a representation. Patent-right is copyright in form, and utility, and methods of production; whether brain imagination be multiplied in printed books, or in music, or in engraving, or artistry, or design, or theatrical exhibitions or shows, or stamped on matter under what are called patents, it is the same process of expressing mind in matter as an origination; and as the originators are comparatively few in number, it is desirable to cultivate them, and give them enclosures of mental domains wherein to have free scope for the exercise of their various arts, for precisely the same reasons that the enclosures and private ownership of land—a common property—is granted to the producers of food, and for other purposes.

It is simply the system of bad laws to which all the evils of patents are traceable. There was a time when, amongst the manufactures of printed fabrics, all new designs were kept secret as far as possible till the moment of issue, and all were busy bribing, or trying to bribe, their neighbours' designers. The Act for Copyright in Designs abolished this system of piracy, and with it the secrecy. Were patents abolished, one of the results would be a return to secrecy in all small things, a closing of manufactories against inspection, and a general dearth of information to mechanical periodicals, while improvements, involving a large outlay of capital, would cease to be made, unless perchance in government establishments.

If the spread of knowledge be a national advantage, the inducement to secrecy by the abolition of the patent —OPEN—would be a serious evil.

Amongst the reasons alleged for the abolition of patents, one is, that the patentees gain no advantage—being ruined by opposition and lawsuits in case of the invention being successful.

This is the greatest farce of all, as if land property would be safer than brain property, were it protected by as bad and inefficient laws as patents are subjected to, and as if there were any difficulty in making as efficient laws for patents as for books and designs, were only influential men interested in bringing them to pass, and lawyers not interested against them.

Another allegation is, that the great mass of modern patents are useless. If they are useless they need not be coveted. If impedimental, they certainly must supply something useful. But it is again alleged that they are frivolous. But is not trade itself widely frivolous? Yet what merchant is there who despises anything frivolous, provided only large profit be mixed up with it? What is more frivolous than the majority of theatrical farces, yet what is there more carefully guarded against piracy? But, say the objectors, patents are granted for things not new, and merely serve as an excuse for lawsuits. That simply means that the law and practice have not yet been fitly established. Some say that patents are becoming so numerous that they cannot keep count of them, and so unwittingly infringe them. This is not logical. The patentee might as well object, "The great manufacturers make so many new things without giving me notice, that I cannot keep count as to my originality." This complaint on the part of manufacturers only proves that they manage their business badly. It is surely part of the business of a great manufacturer to know of everything produced in his special art, and, therefore, he should keep a book of patents as regularly as his price-list, with a managing clerk to it. He can, at small cost, have all the specifications in his trade supplied to him as fast as they come out, and he can index them and mark out all the real novelties and utilities, and put them to use by agreement with the owner. It is said that every British subject is bound to know all the laws, or take the consequence of breaking them, and certainly a British manufacturer is bound to know all the patents in his trade as part of his business.

All existing knowledge and manufacturing experience up to the present time is the joint property of the whole nation, less certain things protected by patents expiring in fourteen years. But these patents are the "Naboth's vineyard," coveted by the lords of trade.

But they may fairly say that amongst the numerous patents there are many fictitious ones, involving lawsuits, and thus deterring them from the use of what is really common stock. That is to say, the patent-laws are bad laws, so bad, that were all laws equally bad, the nation would be in a condition of anarchy. To abolish the patents instead of to reform the law would be a precedent upon which we might abolish all laws.

Let us begin at the beginning. Patents are virtually granted for something new and useful, thereby to teach the public, and the reward for such teaching is a fourteen years' exclusive right. What, then, is novelty?" There is nothing new under the sun, absolutely. The patent is really granted for something new to the existing generation, as an inducement for a skilled man to bring it into use. The title should, therefore, be put on a similar footing to that of land. A piece of unowned land, unclaimed for thirty years, becomes the property of whoever may occupy it, and for ever. Therefore, supposing patents to be in the interest of progress, absence of public use for thirty years should constitute a claim to anything useful as a novelty for fourteen years, or such time as might be deemed equitable.

Everybody of legal age should be competent to apply for and obtain a patent, but as any preliminary examination and refusal might involve an accusation of nepotism or a contingency of error, not afterwards to be amended, it is desirable that protection should be granted, if desired by the applicant, after pointing out to him the defects; and that the specification, after completion, should be put on open, not secret trial, by a competent judge in the presence of the patentee, and the original fees should cover this cost. It is not desirable that a model should be put in at first, as involving the employment of workmen and the risk of discovery before protection is granted; and models being expensive, it is not fair to encumber the patentee with costs.

The affirmation of the patent by the court should facilitate all further litigation as to title and right, the court itself taking the initiative, or acting at the instance of a complainant.

Pecuniary damages should be dealt with by a magistrate, as in the case of copyrights, or by the ordinary courts of law.

Fictitious patents abolished by the court would cease to be a nuisance in the hands of sharking pretenders. There are very few patents requiring deep thought to apprehend them when produced, or any length of time when legal quibbling is abolished.

An inventor should not be bound to license other persons, for the reason that they might be rivals, only taking a licence in order to damage his invention in public reputation. If an unreasonable man, he would damage himself by limiting the use. If a manufacturer, he might be interested in selling at the lowest price without royalty profit, and thus as a small capitalist he might compete with great capitalists by securing the trade in a better article.

If the invention were a small item in a large machine, and the inventor required an unreasonable royalty, that would simply be a stimulus to other inventors to make other improvements, and this would be clearly in the interest of the public.

In cases where the subject of a patent has been in private use previous to the specification, unknown to the patentee, it would become a question for the court to decide as to whether the public had been kept out of the knowledge furnished by the patentee, and, if so, the patent should be confirmed, subject to the use of the first user, but without giving to him the right to license earned by the patentee by his publication.

No excuse of ignorance of a patent should be admitted as a plea or mitigation of infringement, because, with the full means of obtaining the records of the Patent-office, the ignorance must arise either from wilfulness or negligence.

Patents are the Magna Charta of the material progress of a nation, by the agency of the rich brains of men, poor in practical capital, who can mould matter to man's uses after new and useful fashions, just as copyright is the Magna Charta of the nation's progress by the agency of men of rich brains who can mould language to men's uses after new and useful fashions. When laws shall be made to take away this charter and throw brains into common stock, one of the sources of England's eminence, her true equality, will have departed from us, and the trade lords will find that their vitality has departed with it. They will compete with each other with increasing competition and lowering profits, till their trade becomes as wild land, which no one cares to cultivate. They will then find that the fourteen years' mental enclosure, which induces men of thought to bring forth new things, is also one of the processes essential to profit, and that by abolishing it they "kill the goose which lays the golden eggs."

Trade-marks are the legitimate arms and quarterings of a trade aristocracy, guarantees of honesty in execution, and which become valueless as a manufacture becomes debased. They are monopolies in one sense, as they enable the owners to keep to themselves a large trade so long as they keep up their character, and the law now jealously deals with their infringers. The patent is also a trade-mark exclusive for fourteen years, enabling the owner to establish a reputation for originality and improvement, and to keep his reputation when thrown into competition with rivals. And with patents confined to the owners of manufactories, that would simply be establishing a caste of veritable monopolists.

The question has been dealt with thus far simply in the interest of the public, regarding the inventor merely as a part of the public. But the true inventors are more than this—they are a select body of students, who foresee those things that the manufacturing men of routine pass by blindfolded, and thus stir them up to action; and the public is deeply interested in caring for these men, and guarding their interests as their own. From the trade point of view, the mere manufacturer only looks to the profit per-centage attainable by the conversion of raw material into wrought, and would work up the whole raw material of the land, and afterwards throw it into the sea, if realising the per-centage thereby. It is this class of men that deteriorates our national manufactures in money competition, that makes rails as brittle as cast-iron, and delights in shoddy, that has no perception of, or care for progress, but only for money.

It is not thus that the greatness of England has grown; nor is it of the highest importance that inventors should reap enormous fortunes, albeit trifling in proportion to the gain to the general community; but it is desirable that they should be in the unanxious position requisite for the most advantageous pursuit of their studies and experiments, as a result of their own labours.

The nation in which all classes of its people can rise in succession, according to their faculties and cultivation, from the lowest position to the highest, must ever be more powerful than a nation of castes, and a nation without laws efficiently protecting mental as well as physical property must degenerate into a land of castes—or robbers.

There is yet another allegation on the part of opponents of patents. Having to pay a royalty in England, other nations paying no royalty can undersell them. It is scarcely so, for other nations are as desirous of having patents as English people are. Of the two republics, America and Switzerland, the former abounds with patents, the latter has none. The reason is, that in the former case they are a function of the Federal government, in the latter of every separate canton, rendering patents a practical impossibility. But citizens of Switzerland expatriate themselves, and get patents here and elsewhere, and it is probable that the patent branch of legislation will be transferred to the Federal government, and Switzerland will cease to be an exception to other civilised states.

With a climate and condition like that of England, where workmen live longer and do more days' work in every year than in most other countries, it is impossible that she should be undersold in her indigenous manufactures, so long as her materials shall endure. Capital embarked in the growth and training of a workman is profitable in proportion to the length of his working life, and the faithful and honest work produced.

The assumption that every patentee only forestalls a number of other persons, who would have discovered or planned the same thing, may or may not be true, but this does not concern the public. What the public want is individuals who will work, and teach in the best mode he can, something new and useful; and daily experience tells us that such individuals cannot be obtained save on the condition of thereby obtaining a specific sphere of action involving their own benefit as well as that of the public. Let any one try if, by simply publishing a new and useful thing, he can get it taken up unless he can offer an exclusive right with it. Neither is there any probability in the assumption that all the principles of action have been discovered, and that the details are in every one's hands. The tree of universal knowledge is yet far from from having been plucked, and it is to be desired that the men of science, as well as the men of practice, should be not only recognised but rewarded, as the benefactors of the community—not rewarded, as M. Chevalier proposed, by the State, but by the community. We do not want political inventors, with a government reward as a compensation for something other than an invention, and with their own friends to apportion it. We want for them the only true appreciator, the public.

There is no difficulty in remedying all the evils complained of in the present practice of patents. Forms of specifications can be prepared, embodying everything that is required to be stated, leaving no loopholes, and preventing verbiage, giving an exclusive privilege to make something useful, and leaving it open to competition to make something still better. The life of the inventor patentee is no lazy life. He has the public for a master, and a very exacting master too, content with nothing but the best or the cheapest, and ever ready to abandon its idol of to-day for its idol of to-morrow, succeeding each other in constant following. What do the long list of patents in the same arts mean, save that the human brain works only from step to step, eclipsing yesterday by to-day, and thus preparing the way for the morrow, a 'vantage ground being gradually attained, till the process culminates in an apparent perfection, at last found to be no perfection, when a fresh start is made to a new elevation. By the sweat of the brain within his brow the inventor diminishes human labour and the sweat of many brows, for his only profit is out of the service he renders to mankind, who will not pay for anything they do not appreciate as useful or pleasant. No State reward is needed as a stimulus to this kind of labour. The inventor only asks to be let alone to reap the crops he has himself sown, secure against depredation.

It was Prince Albert by whom the amended Patent Law, then being worked at by the Society of Arts, was finally urged, and it was Lord Granville who brought in the Bill and passed it through Parliament, in the course of a very few days, because it was believed that only thus could a number of latent inventors amongst mechanical men be brought to light for the benefit of the Great Exhibition. It was this Bill which, by reducing first cost, multiplied the number of patents, and put poor men more on a level with capitalists. And it would appear that non-inventive capitalists would rather be without these patentees, and would prefer to buy up their inventions for their own purposes, and so limit the public choice in the market. Patents give a large market for constant improvements, which would not exist without them. All the large manufacturing towns and cities of England may be said to be built upon patents, and were patents abolished, the result would be similar to that of the abolition of the Edict of Nantes; the imaginative brains would depart from England, and settle down in the countries wise enough to understand their true interests. Viewed from the monopoly point, the wisest course the manufacturers could take would be, not to abolish patents, but to enhance their cost. If patents cost £5,000 each, with efficient laws to maintain them, every poor man would be shut out, and patents would become the practical monopoly that the manufacturers insist on calling them. But the motive would thus be too gross.

The subject cannot be too widely discussed, nor the facts elicited too clearly, for we cannot as a nation afford to risk our prosperity in order that a small number may grow richer at the general cost. We want a general diffusion of wealth, and not a greater aggregation in masses. Large manufactures tend to the growth of quantity rather than quality. Small manufacturers tend to the growth of quality, and that diffusion of wealth so largely trenched on of late by the gigantic establishments which permit only two classes, the very rich and the very poor. The higher classes, living on incomes, the result of land or hoarded wealth, are deeply interested in the question, for it is a question of property right; and in the diffusion of property rather than in its concentration lies its safety. The convenience or profits of manufacturers is but a small consideration, as well as the convenience or profits of inventors. The national prosperity is the real question at issue. Shrewd Frenchmen tells us that we began patents some fifty years before them, and, therefore, they have never been able to overtake us. Were we now to abolish patents for fifty years, our human energy would be expended in producing original workers for all other nations, and excluding our own.

Patents.

From Commissioners of Patents' Journal, July 23.

GRANTS OF PROVISIONAL PROTECTION.

Ammonia, generation and treatment of—2116—I. Baggs.
Animal and vegetable substances, preserving—2028—G. Buchanan.
Artesian wells, application of pumps to—2105—C. Chapman.
Bedsteads, &c., knobs for—2078—T. Kendrick.
Boilers—2051—W. Arnold and W. Carnelley.
Boilers, &c.—1716—J. Stewart and T. Charlton.
Boot and shoe scrapers - 2043—F. Walton.
Breakwaters, &c.—2074—J. W. Jackson.
Cartridge boxes—2099—C. Mertens.
Cartridges, &c.—2076—C. E. Brooman.
Casks, preventing waste of liquids in filling—2041—D. Cope.
Cast-iron, converting into forgeable steel—2108—C. P. E. Roche.
Cotton, &c., machinery for preparing and spinning—2100—E. Pettitt.
Dovetails, machinery for cutting—2049—J. Robinson.
Electric currents, apparatus for producing—2062—I. L. Pulvermacher.
Fabrics, finishing fibrous and textile—2082—S. Read.
Fabrics, &c., drying, airing, and warming—2085—J. Bannehr and H. Matthews.
Fire-arms—1992—T. Jones.
Fire-arms, breech-loading—2115—J. Barnett.
Fire-arms, &c., breech-loading—2071—F. J. Manceaux.
Fish hooks—2061—I. Williams and R. C. H. Wallendahl.
Food, &c., treating certain substances for—2092—J. Dewar.
Grain, cleansing—2098—C. D. Abel.
Heating apparatus—2114—S. E. Crispe and J. West.
Horse shoes—2084—J. B. Couper, jun.
Horse shoes, machine for manufacturing—2088—W. R. Lake.
Iron and steel—2047—R. Mallet.
Kitchen cart to be used for military and other purposes—2080—C. L. Caldesi.
Lamps—2067—J. H. Jones.
Lamps—2070—G. A. Nowell.
Letter boxes, &c.—2093—C. A. Bates.
Looms—2068—M. A. Muir and J. McIlwham.
Marquetry, &c., producing—2087—W. R. Lake.
Match boxes, &c.—2055 - R. P. Faucheux.
Moneys, coins, and medals, manufacturing—755—J. M. Napier.
Motive-power, obtaining - 2069 - J. Aitken.
Mowing and reaping machines - 2112—A. V. Newton.
Paper, beating engines employed in the manufacture of—2123—J. W. Reid.
Paper-making machinery—2111—R. Craig.
Phosphorus, utilising the residual sulphate of lime produced in the manufacture of—2101—J. H. Player.
Pumps—2081—J. Beard.
Railway level-crossing and other gates—2066—F. Baker.
Railways—2060 T. Knowles.
Reaping and mowing machines—2057—J. G. Rollins.
Rick stands, iron vermin-proof—2096—W. Bayliss.
Shafting and gearing, couplings and wheels for—2091—Q. Dunlop, T. J. Martin, and W. Orr.
Shaving mugs—2058—J. Wright.
Ships' sails - 2109—W. P. Bain.
Speaking pipes 2094—E. Sutton.
Speaking tubes, &c., spring-stopper for closing mouth-piece of—2124—J. Leetch.
Squares for finding the centres of circles, &c.—2056—C. S. Berthon.
Steam-engines, boilers, and furnaces—2083—J. S. Crosland.
Stoves or fire-places - 2120—T. Richards.
Submarine cables, appliances for finding and for picking up—2121—R. Willcox.
Sulphuric acid, recovering nitric acid in the manufacture of—2077—J. Gessert.
Surface condensers and refrigerators—2097—J. Henderson.
White lead—2102—W. R. Lake.
Windlasses—1905—W. Clarke and E. Walker.
Wood-sawing machinery, &c.—2090—W. R. Lake.

INVENTIONS WITH COMPLETE SPECIFICATIONS FILED.

Artificial fuel, &c., moulding—2195—S. Hall.
Blasting, and apparatus employed therein—2166—J. H. Johnson.
Blotter or ink absorber—2179—V. E. Mauger.
Fire-bars—2155 - P. Murray.
Pianoforte bridges 2119—J. A. Horlick.
Pianoforte hammers—2118—J. A. Horlick.

PATENTS SEALED.

226. R. G. Lowndes and M. M. Callum.	273. J. Box.
229. J. Carr.	278. J. Pickering.
241. J. Wilson.	307. J. A. Limbert.
243. W. R. Lake.	317. A. E. Harris.
252. T. Vaughan & J. W. Smith.	332. C. E. Brooman.
253. H. Barcroft.	374. H. A. Bonneville.
256. J. H. Johnson.	399. L. A. C. St. P. de Sinçay.
261. C. Lungley.	558. A. Jobson.
262. A. C. Pass.	637. J. Townsend and P. Forbes.
266. W. Brown and T. H. Garbutt.	1075. G. D. Hughes and A. H. Sellers.
	1469. J. Townsend and P. Forbes.

From Commissioners of Patents' Journal, July 27.

PATENTS SEALED.

270. R. Blackbee.	428. G. A. Nowell.
272. L. P. Hébert and L. A. Moulin.	432. B. P. Stockman.
276. G. Hawksley.	477. F. Walton.
280. J. McDonald.	699. J. P. Budd.
289. T. Whimster.	728. T. Obach.
302. A. S. Andrews.	737. F. O. Palmer.
319. W. A. Smith.	781. J. and W. Thomlinson.
320. J. Bird.	820. J. Ramsbottom.
330. C. D. Abel.	914. C. Marsden.
340. H. and J. Bryceson and T. H. Morten.	928. N. Voice.
347. R. W. Knowles and G. Green.	1036. A. Helwig.
389. H. J. Richman.	1167. J. Vivian.
390. F. Jenkin.	1351. R. Saunders.
408. W. Hilton.	1360. F. W. Kaselowsky.
418. G. Broadhurst and J. Kershaw.	1551. J. Langham.
	1554. A. J. Dudgeon.
	1591. L. J. Crossley & R. Hanson.
	1694. J. A. Bindley.
	1730. G. W. Ley.

PATENTS ON WHICH THE STAMP DUTY OF £50 HAS BEEN PAID.

1890. H. Trotman.	1965. T. and J. Bibby.
1906. E. Leigh, H. T. Palmer, and W. E. Whitehead.	1912. G. T. Bousfield.
1935. J. Vavasseur.	1957. J. Phillips-Smith.
1948. W. Weldon.	1968. J. A. Birkbeck.
1953. J. Orr.	1982. J. Robinson.
	1941. H. A. Bonneville.

PATENTS ON WHICH THE STAMP DUTY OF £100 HAS BEEN PAID.

2956. M. and R. M. Merryweather and E. Field.	2130. W. Spence.
	2108. W. Clark.